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Special Technical Report 36

SELECTED EXAMPLES OF VHF SIGNAL PROPAGATION RECORDS IN TROPICAL TERRAINS

By: N. K. SHRAUGER E. M. KREINBERG

Prepared for:

U.S. ARMY ELECTRONICS COMMAND
FORT MONMOUTH, NEW JERSEY 07703

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SRI Project 4240

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ABSTRACT

Slow-speed chart records of received signal strength showing the perturbations caused by scattering from trees in the VHF band are presented. Data for several frequencies and polarizations of transmitting and receiving antennas (simple dipoles and standard AN/PRC-25 manpack-set whips) are included, as well as a variety of combinations of clearings, jungle terrain, rubber plantations, and bamboo. The records permit a qualitative evaluation of the magnitude of signal fading that is superimposed upon the smooth decrease of received signals with distance between transmitter and receiver. Some similar results are presented for an AN/PRC-25 manpack system using AT-271/PRC antennas.

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ILLUSTRATIONS

I INTRODUCTION

A major effort by Stanford Research Institute under Project SEACORE is directed toward solving problems of manpack radio communication in a tropical environment. A recent phase of this effort is to document the effects of terrain on received VHF signals at several frequencies and polarizations, and at low antenna heights. The technique using the manpack Xeledop (transmitting elementary dipole with optional polarization) is described in detail in a Special Technical Report,[1*] which discusses the test method, and the results obtained from early studies. Similar tests were made at Chumphon using an AN/PRC-25 manpack system with AT-271/PRC antennas (10-foot whips). The examples presented in this report were selected from a large number of records that were made during an extensive measurement program near the towns of Chumphon and Chantaburi, Thailand.[†] These selected records permit a qualitative evaluation of the signal fading and rate of diminution with distance for open and forested terrains and various frequencies and antenna polarizations.

*References are listed at the end of the report.

†Chumphon is located in southern Thailand on the Malay Peninsula near the Isthmus of Kra. Chantaburi is in southeast Thailand on the coast near the Cambodian border.

II TEST DESCRIPTION

A. Xeledop System

The tests described in this report were carried out with a technique based on the use of a Xeledop transmitter. The Xeledop was developed for use in measuring the radiation patterns of full-scale HF and VHF antennas.[2,3] The chief characteristics of the Xeledop transmitter are its stable frequency and constant power output, and its elementary dipole radiation pattern when in free space. Tests have shown that the power output varies less than 1 dB and that the frequency drift is negligible over a period of eight hours. The Xeledop incorporates three crystal-controlled transmitters that are coupled to the dipole antenna through a multicoupler circuit, transmitting at a power of 1/3 watt on each frequency. The unit is designed to transmit CW signals on three frequencies simultaneously or in pulsed sequence on 50, 75.1, and 100 MHz. The simultaneous CW transmissions were used to obtain the data presented in this report.

The VHF Xeledop is small enough to be carried on a back pack, as shown in Fig. 1. The experiment consists of having a man carry the Xeledop along a surveyed trail (which is marked at intervals corresponding to the radial distances from the receiving antenna) and recording the signal strength at the receiver position. The receiving end of the system consists of stable receivers (R-390s with crystal-controlled converters) fed with unbalanced, resonant half-wave dipole antennas. The feed point of these antennas was placed 10 feet above ground. The converter input was padded to 50 ohms with a 10 dB series attenuator and the resulting minimum usable signal was -110 dBm. The receivers have provisions for obtaining an output that can be directly related to the received

FIG. 1 MANPACK XELEDOP IN HORIZONTALLY-POLARIZED POSITION

signal strength. This output is continuously recorded on a 4-channel paper-strip-chart recorder to which a callibration of signal strength is added. Up to four signals having different frequencies or polarizations can be simultaneously recorded with this set-up. As the Xeledop transmitter is moved along the trail, a second man carrying a small hand-held transceiver walks several wavelengths ahead of the transmitter. His job is to relay to the recorder operator the transmitter's position as it is carried past each of the radius markers. These distances are marked on the chart record of the received signal strength by the receiving-site operator. (A chart speed of 1 mm/sec was used.) Thus, the experimental results are obtained as a calibrated, paper-chart recording of received signal vs. radial distance.* The calibration of signal strength is in dB above 0.7 μV across the 50-ohm receiver input for all records except the AN/PRC-25 data where the reference voltage was 2.2 μV across 50 ohms (see Sec. II-B).

The Xeledop measurements were conducted over several trails and terrains for 50, 75.1, and 100 MHz. Four polarization combinations were used: V-V, H-V, V-H, and H-H. (The first letter refers to the Xeledop transmitter, the second to the receiving antenna.)

B. AN/PRC-25

Some data runs were conducted in the rain forest site (Chumphon) using AN/PRC-25 radio sets equipped with 10-foot-long whip antennas (AT-271/PRC). An AN/PRC-25 transmitter was carried

*The trails were surveyed and marked in units of radial range. In cases where the trails were not linear, or where the man carrying the Xeledop did not walk with constant speed, the abscissa (distance scale) on these records was not precisely linear. Nevertheless, the distances marked on the chart record were radial ranges, and the distance scale is approximately linear for the example records presented in this report.

over the test trail in the same fashion as the Xeledop transmitter. An AN/PRC-25 set with its receiver modified for recording the signal variations appearing at the emitter of the fourth limiter stage was used at the receiving terminal. Received signal-versus-distance records comparable to Xeledop records were thus obtained. The radio sets were supplied by 12 V, 30 amp-hour motorcycle batteries to ensure constant dc input power during the trials. Details of this instrumentation are given in Ref. 4.

III TERRAIN DESCRIPTIONS

A. Tropical Rain Forest

Most of the records in this report are taken in a fresh-water tropical rain forest on the Malay peninsula near Chumphon, Thailand, a few hundred miles south of Bangkok. There, trees are very numerous, having straight boles (trunks) and a rather dense, uniform canopy (Fig. 2). The forest has a mean height* of 12 meters, and 90% of the trees are less than 27 meters high. Most of the forest area is covered with an undergrowth of broad-leaf and thorny plants that is about 2 to 3 meters in height and easily removed by cutting (Fig. 3).

The forest floor is very wet, usually covered with 3 to 10 inches of water. This standing water necessitated the construction of board walks to allow carrying the transmitters at a fairly constant pace (Figs. 4 and 5).

Figure 6 is a diagram of the forest and terrain along the two trails that were used in this investigation. The number and size of trees along Trail A were reasonably uniform. At the beginning of the tests, undergrowth immediately bordering Trail A was cut for about the first 0.1 mile into the forest. Later, the underbrush along Trail A was removed for about 100 feet either side of the trail and a distance of 0.25 mile into the forest. This clearing of the undergrowth was done in order to determine whether the Xeledop tests could differentiate between the presence and absence of undergrowth. Trail B was chosen to lie along the edge of the boundary between large trees and existing undergrowth.

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*A detailed report[6] on foliage and soil characteristics is in preparation. The electrical properties of the ground and vegetation at this site are documented in Ref. 6.

FIG. 2 AIR VIEW OF CHUMPHON TEST AREA

FIG. 3 FOREST AND UNDERGROWTH AT CHUMPHON TEST AREA

FIG. 4 TRAIL A THROUGH CHUMPHON TEST AREA

FIG. 5 MANPACK XELEDOP TESTING AT CHUMPHON SITE (Trail A)

As one can note from Fig. 6, this trail passes a few large trees at the beginning, goes through an area of undergrowth only, then passes through a section of large trees, proceeds through a portion with large trees on one side and underbrush on the other, goes through a relatively long portion with large trees on both sides, and then passes through the center of a small clearing. Thus, a variety of large tree/underbrush combinations was obtained along Trail B.

B. Rubber Plantation

Several test records in this report were taken in a mature, undergrowth-free rubber plantation located near Chantaburi in southeastern Thailand. The trees in this plantation were of uniform height (Fig. 7) and were growing in rather uniform rows (Fig. 8). The trees had a separation between rows and columns of about 3 meters, and an average diameter (1.3 meters above ground) of 24 cm. The height of plantation trees averaged 18 to 20 meters.

Xeledop tests were conducted along the two trails shown in Fig. 9, a plan-view sketch of this site. Trail R-1 was laid through both clearing and rubber trees. The Xeledop was carried from the receiving antennas located at Point A, across the clearing and into the forest (Point B). The runs then continued along the centerline between two rows of trees inside the forest, stopping at Point C. Figure 10 shows the clearing and boundary portions of Trail R-1, while Fig. 8 is an interior view of the plantation portion of this trail. In order to present a sharp boundary to the Xeledop, small bushes and trees were removed for 100 feet on either side of the test trail.

Trail R-2 lies entirely inside the rubber plantation. The receiving antennas (and the start of the Xeledop runs) were located at Point D (Fig. 9). The first portion of this trail was in an

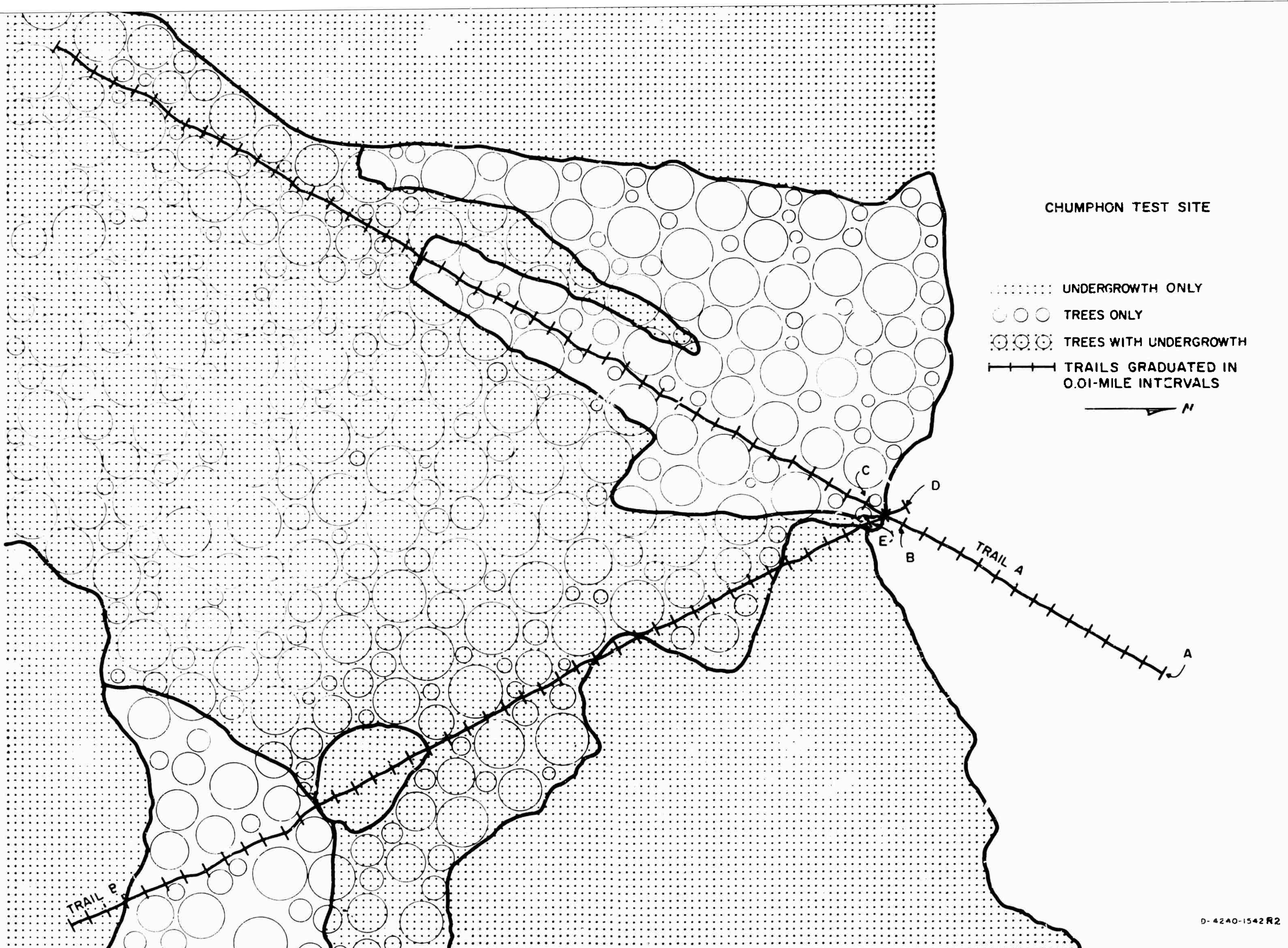

FIG. 6 PLAN VIEW OF RAIN FOREST TEST SITE (Chumphon)

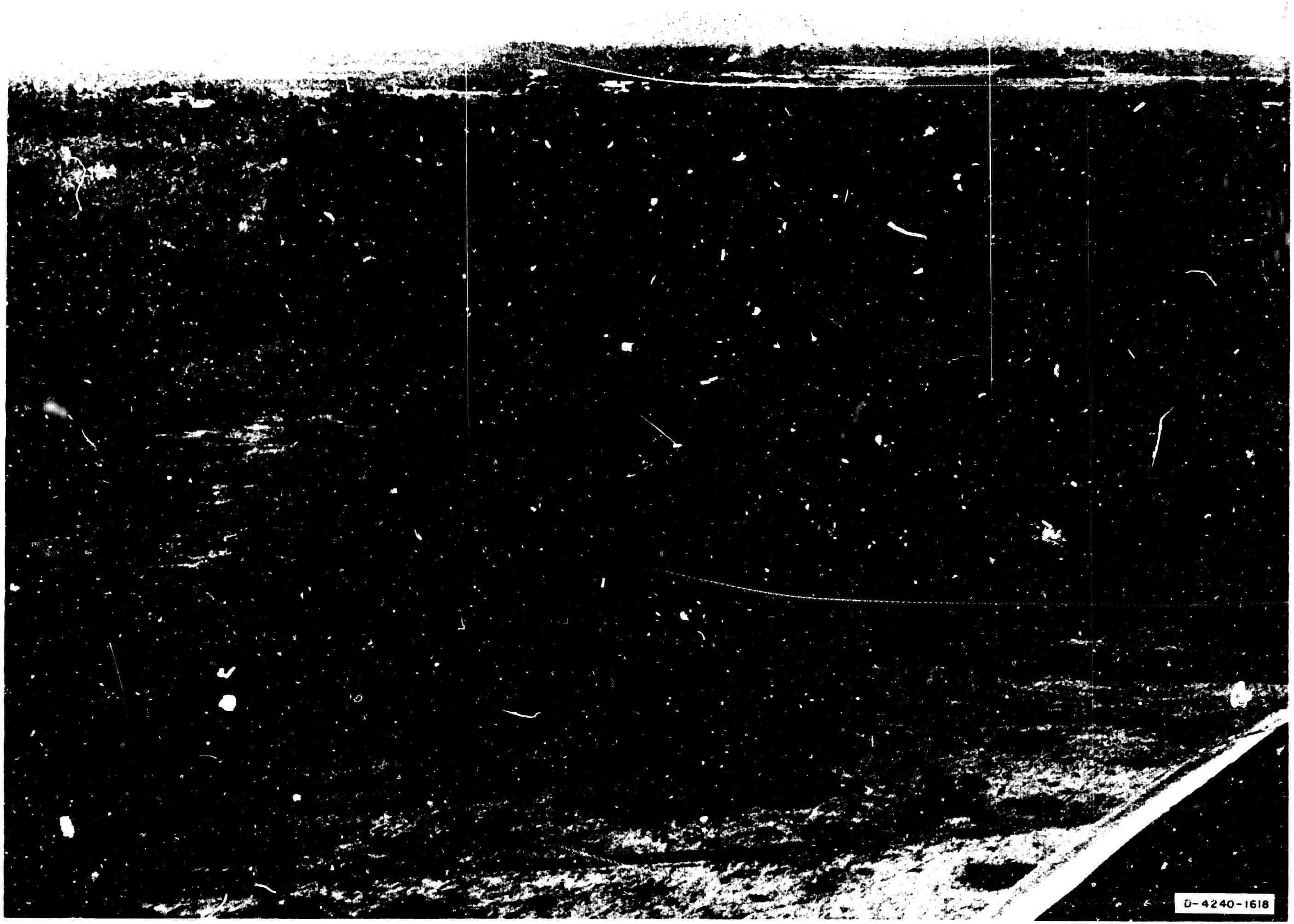

FIG. 7 AERIAL VIEW OF TRAIL R-1 SHOWING CLEARING AND RUBBER PLANTATION

area that had not been used for some time and in which the undergrowth had become quite heavy. This undergrowth was cut (and left to die) for 100 feet on either side of the trail. The undergrowth cut to make the trail itself was removed to either side. Figure 11 is a veiw of Trail R-2. Again the Xeledop was carried on a line centered between two rows of trees. Trail R-2 was only straight in segments, however (see Fig. 9), since the trees were in rows according to small plots owned by individual families.

C. Bamboo

A brief experiment was conducted to determine effects of bamboo foliage on VHF propagation. The bamboo test site, also near Chantaburi, was in an area containing large patches of bamboo intermixed with marshy clearings and rice paddy fields (Fig. 12). The bamboo was about 4 to 6 meters in height and very dense. The ground was very wet at the time of the measurements; in fact, 10 days before the measurements the ground was 6 to 8 inches under water. Thus, this foliage can be classified as "wet bamboo."

The test trail, although short, was such that the Xeledop signals traveled through a nearly continuous patch of bamboo. Figure 13 is a plan view of the site. The receiving antennas were immersed in the bamboo at a convenient location. Because there was not time to obtain permission to cut a test trail through the foliage, the test trail was located along a canal that crossed through the site. The starting point (A) for Xeledop runs was 0.07 mile from the receiving antennas. The Xeledop was carried along the edge of the foliage such that an ever-increasingly direct path through the bamboo existed between the Xeledop and the receiving antennas.

FIG. 8 INTERIOR VIEW OF RUBBER PLANTATION (Trail R-1)

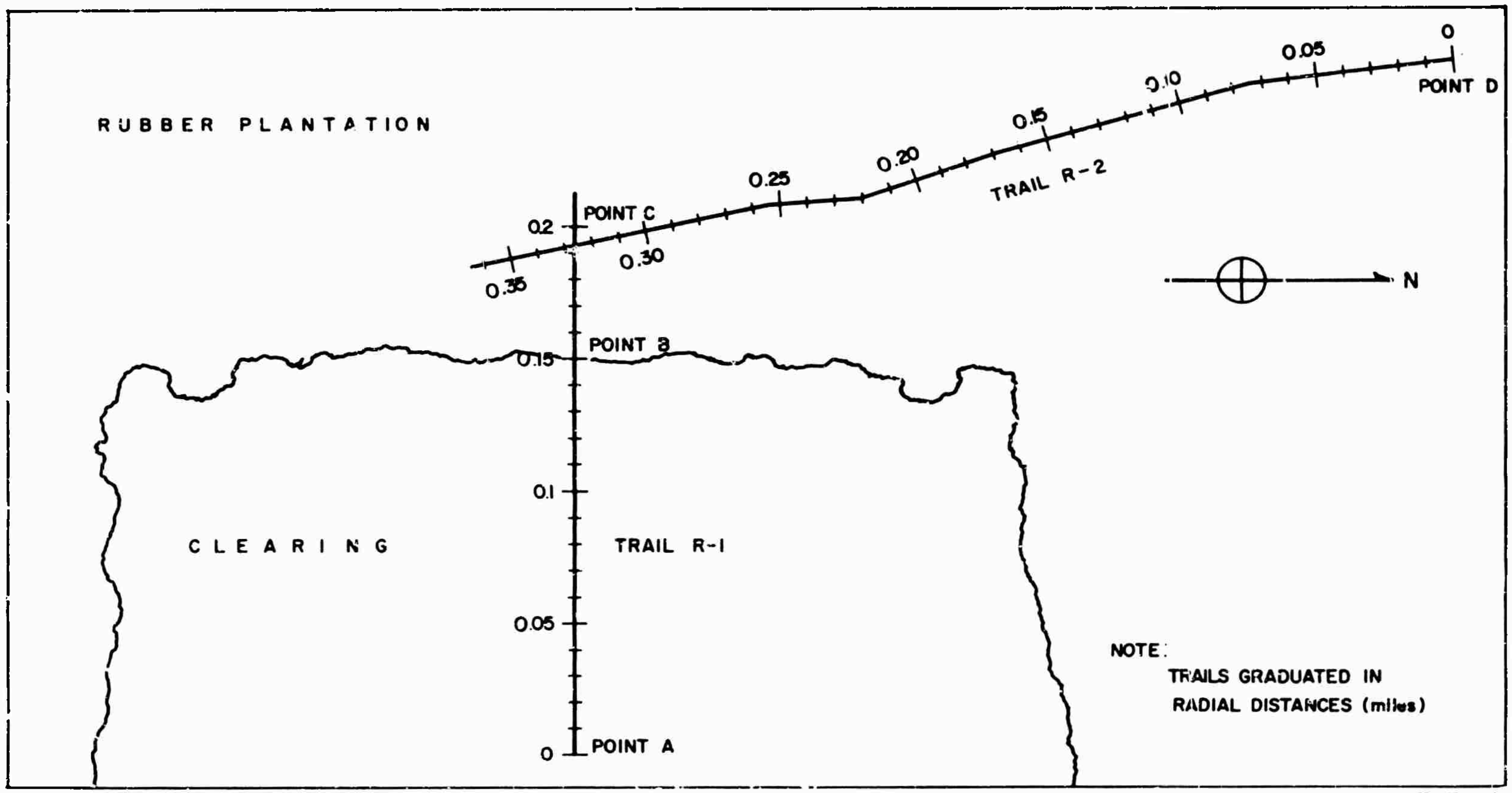

FIG. 9 PLAN VIEW OF RUBBER PLANTATION TEST SITE (Chantaburi)

FIG. 10 CLEARING AND PLANTATION BOUNDARY OF TRAIL R-1 (Rubber)

FIG. 11 INTERIOR VIEW ALONG TRAIL R-2 (Rubber)

FIG. 12 BAMBOO TEST SITE (Chantaburi)

IV EXAMPLES

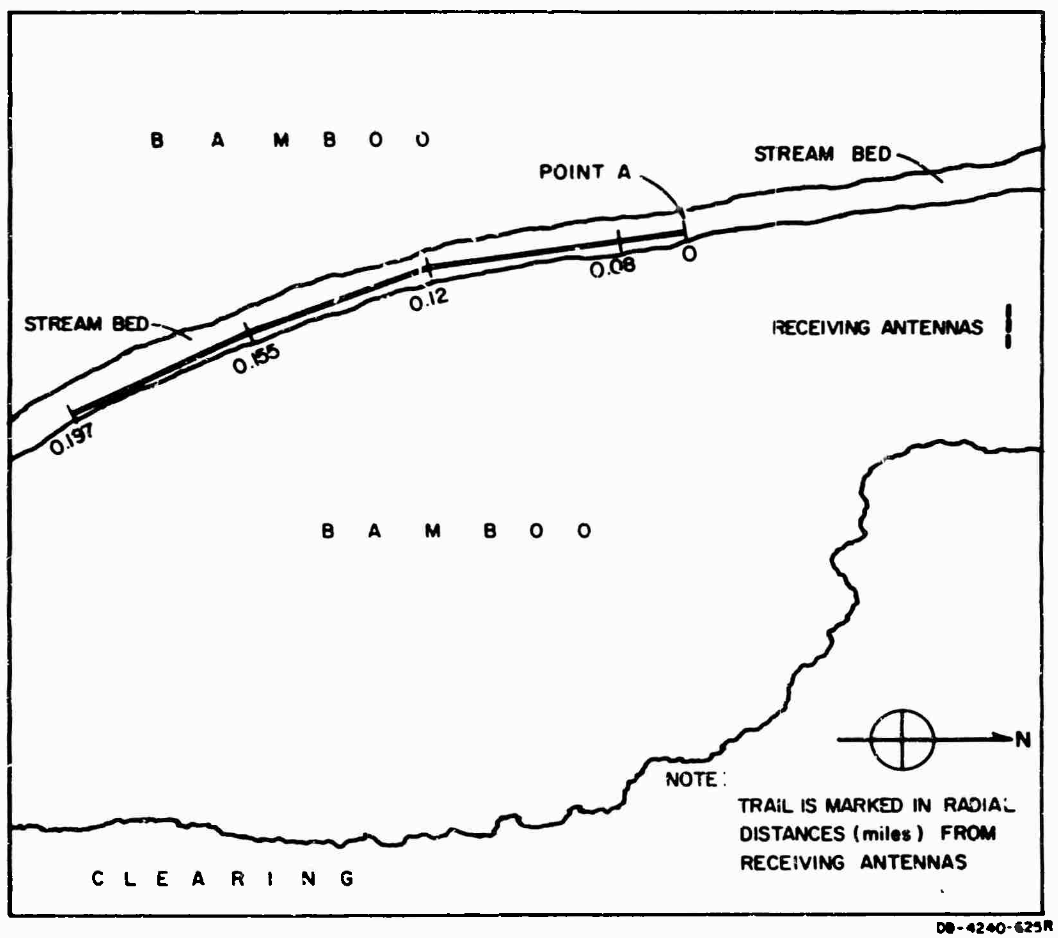

FIG. 13 PLAN VIEW OF BAMBOO TEST SITE (Chantaburi)

The variation of signal strength with distance for a wide variety of conditions and three terrains is shown in Fig. 14 through 33, grouped at the end of the text. At the top of Fig. 14 through 27 is a reproduction of the actual chart recording made during the Xeledop or AN/PRC-25 runs. In most cases separate traces are shown for 50, 75, and 100 MHz. Below the recordings on Fig. 14 through 27, the nature of the terrain is shown schematically and a distance scale between the receiving antennas and points along the test trail is given. The sketches of the foliage are typical but do not indicate more than the general structure of the terrains where the test runs were carried out. Location of the receiving antennas is indicated on each distance scale and also by the capital letter in parentheses in the figure title (e.g., Point B). The test geometry may be identified by reference to the site maps (Figs. 6, 9, and 13).

Two comments concerning interpretation of these data should be noted. First of all, these records are presentations of the raw data. Antenna efficiencies and cable losses have not been accounted for. Thus, the records should not be used to make frequency comparisons of the magnitude of the received signal.* Second, examination of Figs. 14 through 33 shows many of the signal traces reaching and remaining at 0 dB over the latter portions of the test runs. The reason for this is that the lower end of the dynamic range of measurement has been reached. (All receivers were calibrated for the same 0-dB reference.)

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*Detailed comparisons of medians in terms of frequency, polarization, or other parameters can be found for tropical rain forest in Ref. 4.

A. Tropical Rain Forest

Most of the examples in this report were taken from Xeledop runs on Trail A in the rain forest near Chumphon (Figs. 14 through 27). Figures 14 through 17 show the variation of signal strength at three frequencies for vertical-to-vertical, horizontal-to-horizontal, and two cases of crossed polarization. For these runs the receiving antennas were placed about 50 feet inside the clearing from the forest boundary. Figure 18 illustrates, for horizontal polarization and two frequencies, the effect of foliage around the receiving antenna upon the received signal. The four recordings shown in this figure were made simultaneously with two receiving antennas about 50 feet outside and two antennas about 50 feet inside the forest. Figures 19 and 20 show the results of measurements made with two AN/PRC-25 VHF manpack radios in an experiment similar to the manpack Xeledop runs. The receiving AN/PRC-25 was modified to permit the recording of a voltage that was proportional to the received signal strength, and the transmitting AN/PRC-25 was carried along the trail in the conventional manpack manner.* In addition to illustrating the effect of scattering of trees upon the signal received by the AN/PRC-25, Figs. 19 and 20 give some indication of the effect of removing underbrush along the trail between the 0.1 and 0.25 mile markers. It is difficult to discern much, but with the underbrush removed (Fig. 20), the fading appears somewhat less severe.

Figures 21 and 22 illustrate the marked perturbation in the received VHF signal when the receiving antennas are well in the clear and the transmitter approaches the boundary of the forest. For these runs the receiving antennas were placed 0.15 mile from the forest boundary and the Xeledop transmitter was carried on a straight line twoard the boundary, starting at the receiving antennas, passing the forest-clearing interface, and continuing nearly one-half mile inside the forest. A considerably larger boundary effect was observed for horizontal polarization than for vertical. Figure 23 is an expanded distance scale version of Fig. 21, to show the boundary effect for horizontal polarization in more detail.

Figures 24 through 27 show the results of Xeledop measurements along Trail B, which intersects several clearings that are separated by portions of the forest. The schematic drawings of trees and undergrowth shown at the bottom in these figures correspond approximately to the groupings of vegetation along Trail B (plan shown in Fig. 6). In general, in the signal records it was impossible to effectively differentiate between presence and absence of undergrowth along those portions of the trail having large trees. There are indications on some of the records (e.g., 50 MHz, Fig. 25, 100 MHz, Fig. 26) that signal strength increased where there were no large trees (0.25 to 0.30 mile on Trail B), but more data would be required to document such a recovery effect.

B. Rubber Plantation

The test runs at the rubber plantation site provided an opportunity to observe the effect of a rather regular matrix (Figs. 8 and 11) of trees on the received signals. These runs also provided information about the effect of a sharp, regular plantation-clearing interface on the signals.

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*The AN/PRC-25 records show the effect of maximum limiting for the first part of the trail, where the distance between transmitter and receiver is so small (i.e., the received signal is so large) that the set is fully limited. Variations of this voltage do not begin until a distance of about 0.05 mile is reached. This effect could be eliminated by inserting an attenuator between the antenna and the first stage of the receiver, but this was not judged to be necessary for the purposes of these tests.

Four figures are presented to show the rubber plantation results. Figures 28 and 29 give the boundary effect as the Xeledop is carried from the clearing toward and into the plantation. Receiving antennas were located at Point A of Fig. 9. The other two figures (30 and 31) show the signal perturbations experienced as the Xeledop is carried over a longer trail entirely within the plantation. The receiving antennas were located in the forest as well.

C. Bamboo

Two examples of VHF signal propagation through bamboo are given in Figs. 32 and 33. The antennas were located inside the bamboo, but because of the nature of the trail, the starting point for the Xeledop was further down the trail (see Fig. 13). Thus, in these figures, the signal trace begins at 0.07 mile from the receiving antennas.

The bamboo contained no large stems. Thus, signal fluctuation, as expected, was very small compared to that in the rain forest or rubber plantation results.

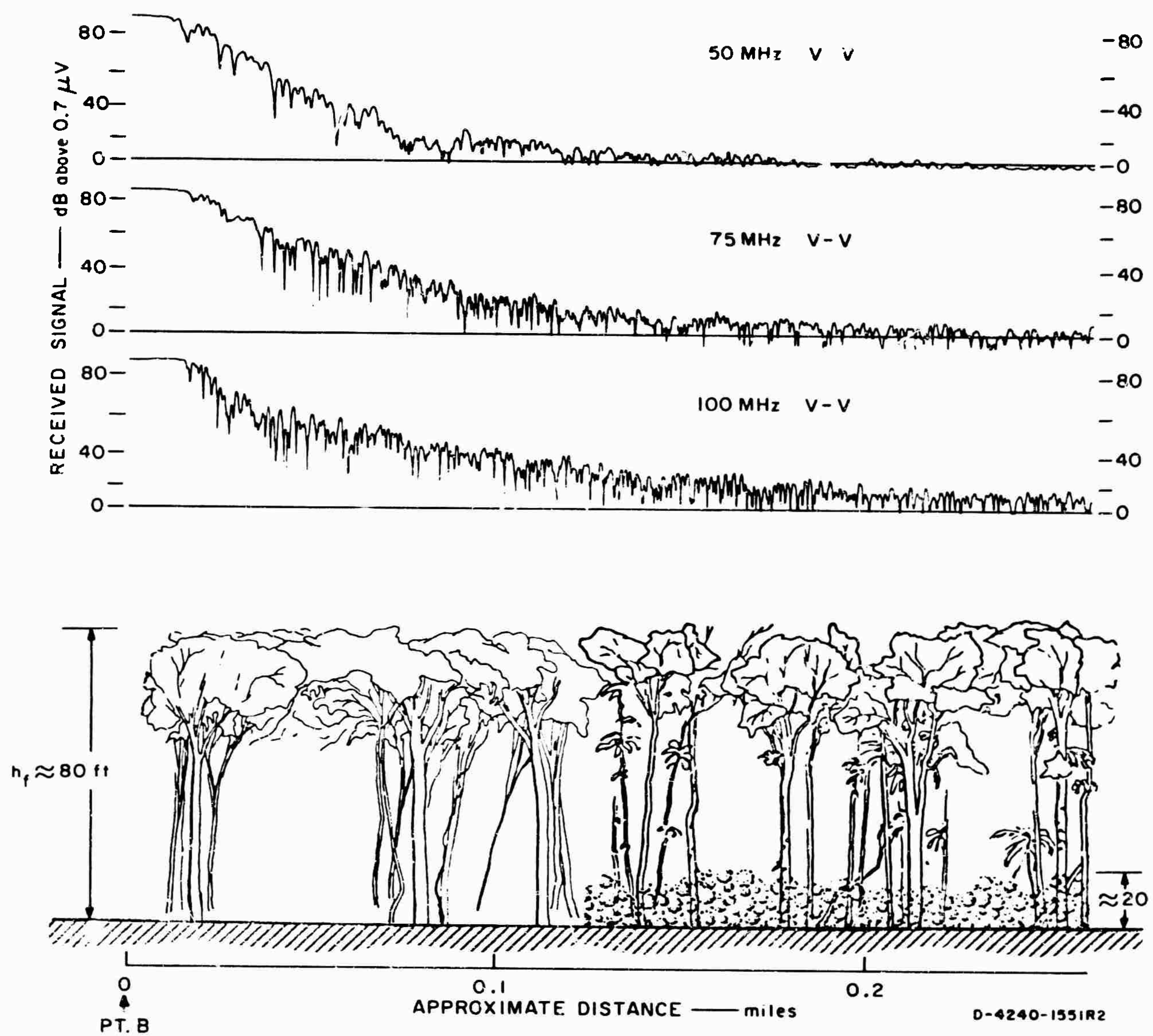

FIG. 14 VERTICAL POLARIZATION: XELEDOP ALONG TRAIL A; RECEIVING ANTENNAS IN CLEARING (Point B)

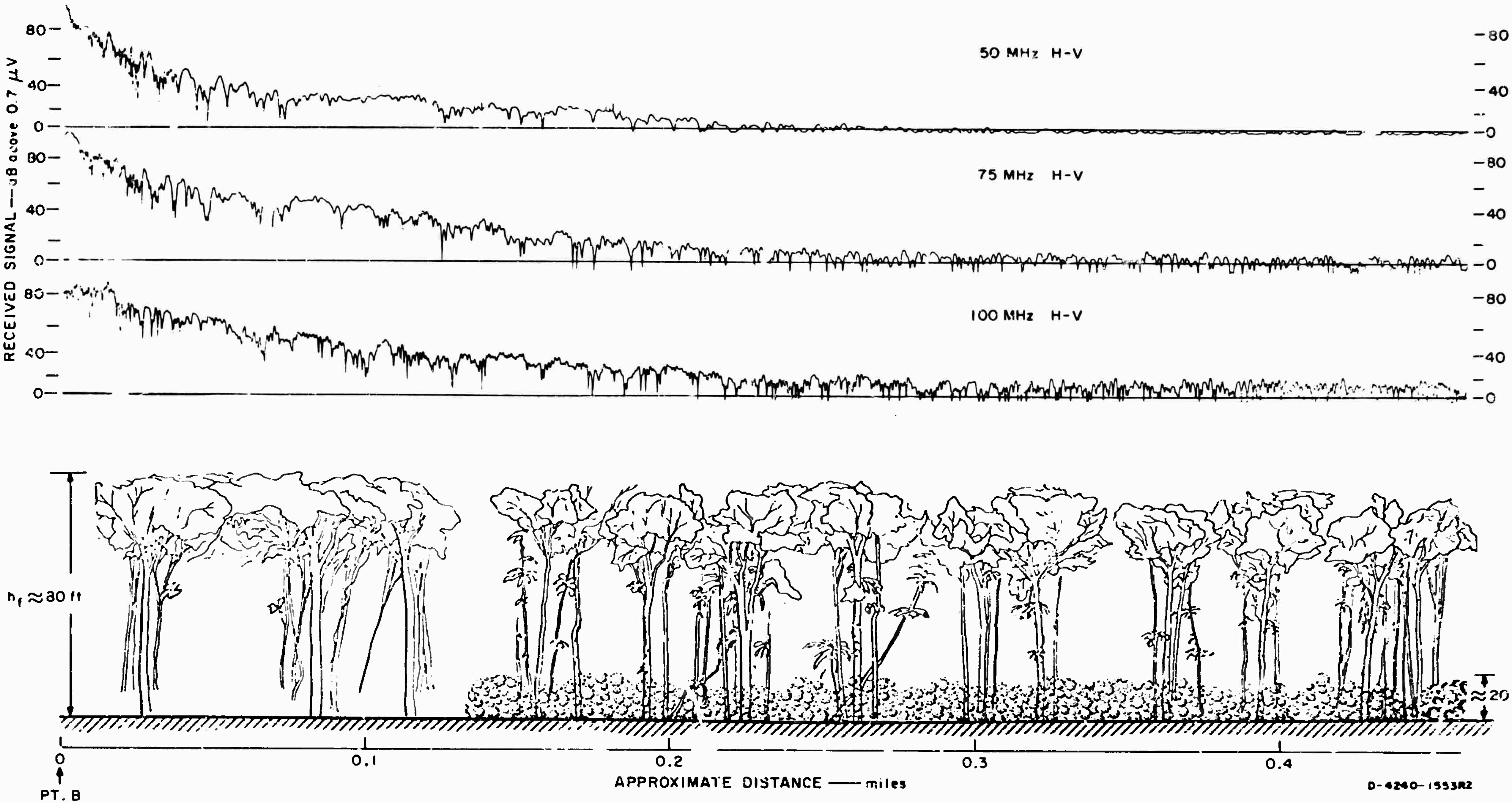

FIG. 15 HORIZONTAL-TO-VERTICAL POLARIZATION: XELEDOP ALONG TRAIL A; RECEIVING ANTENNAS IN CLEARING (Point B)

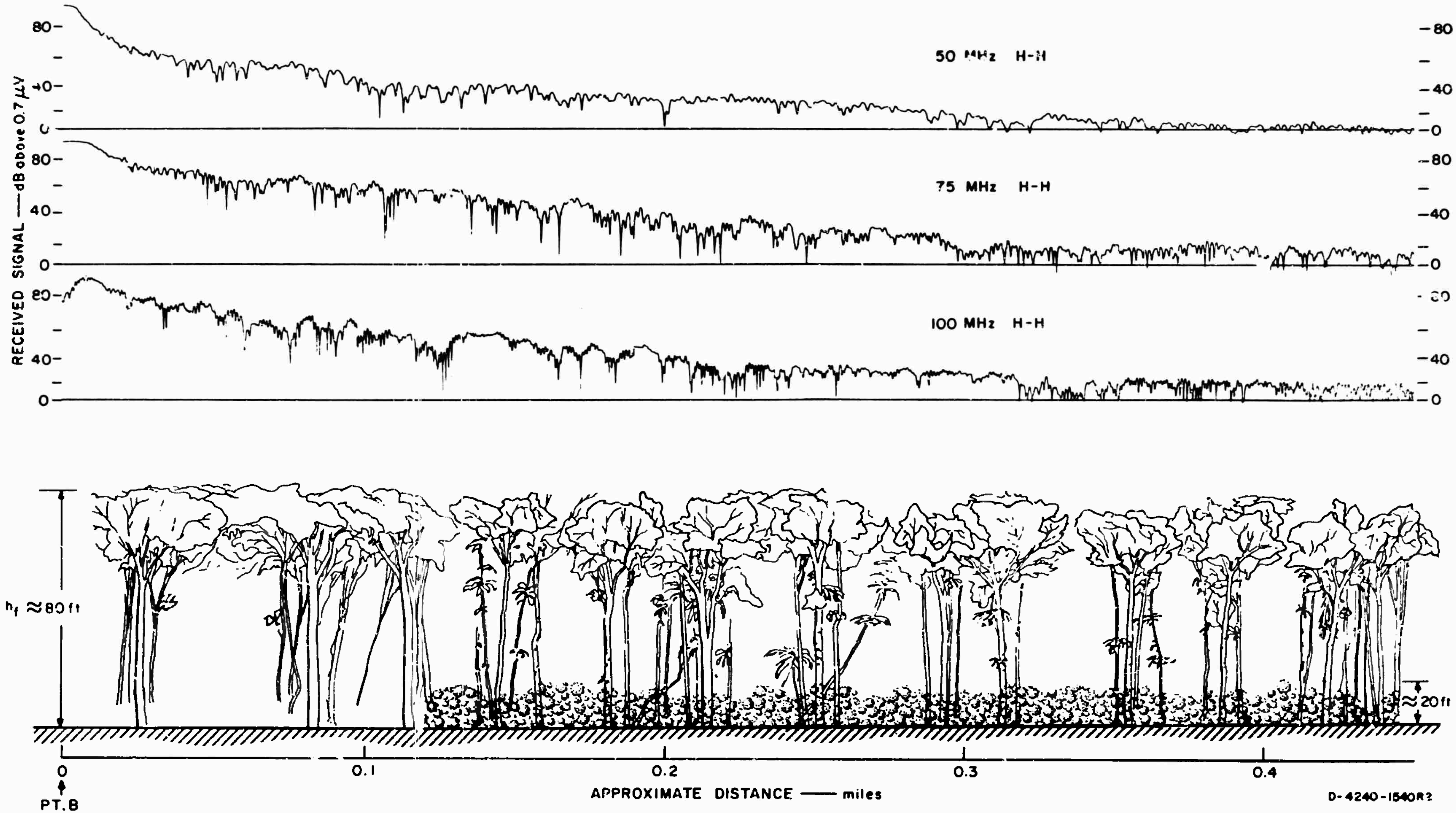

FIG. 16 HORIZONTAL POLARIZATION: XELEDOP ALONG TRAIL A; RECEIVING ANTENNAS IN CLEARING (Point B)

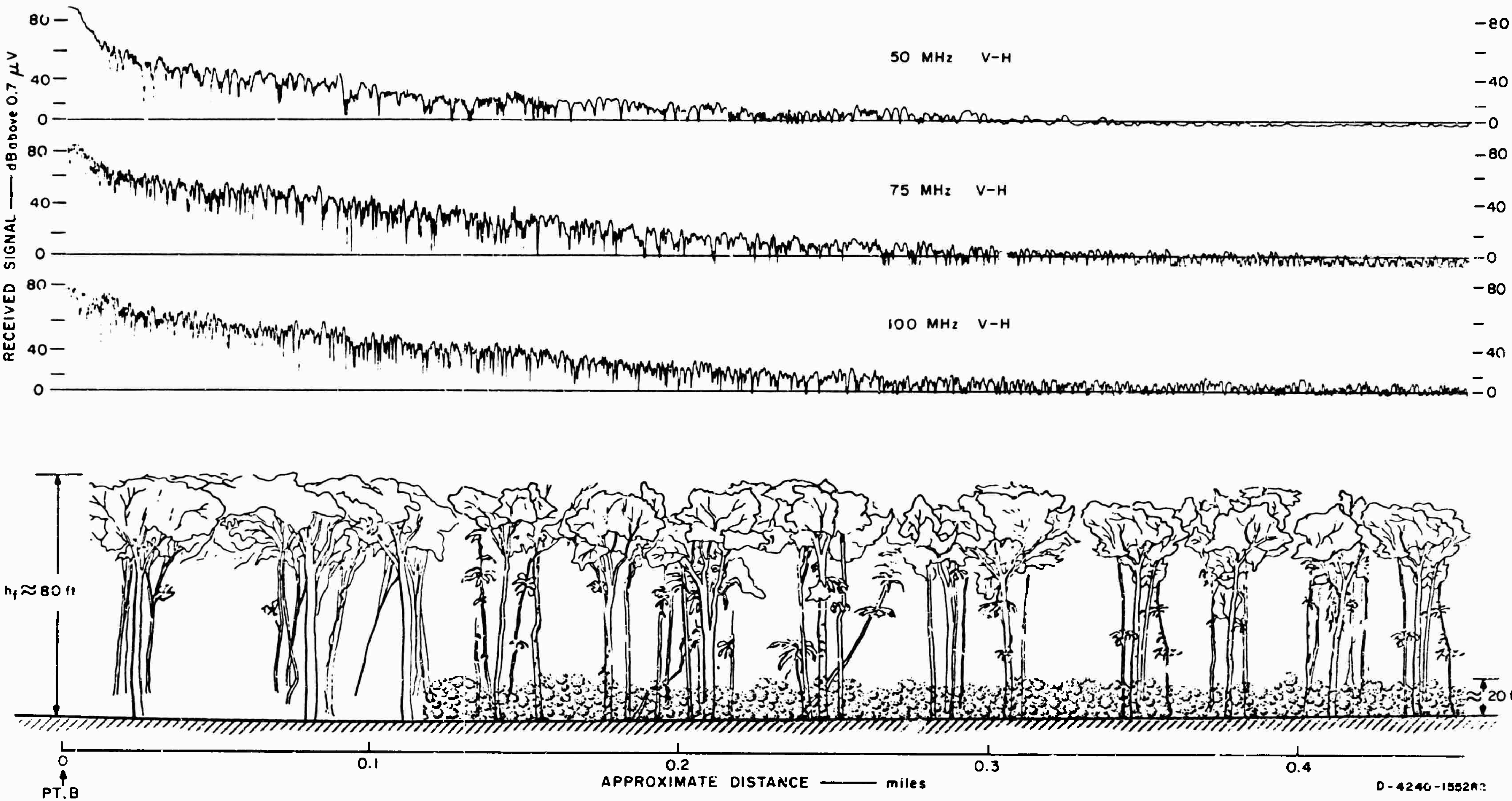

FIG. 17 VERTICAL-TO-HORIZONTAL POLARIZATION: XELEDOP ALONG TRAIL A; RECEIVING ANTENNAS IN CLEARING (Point B)

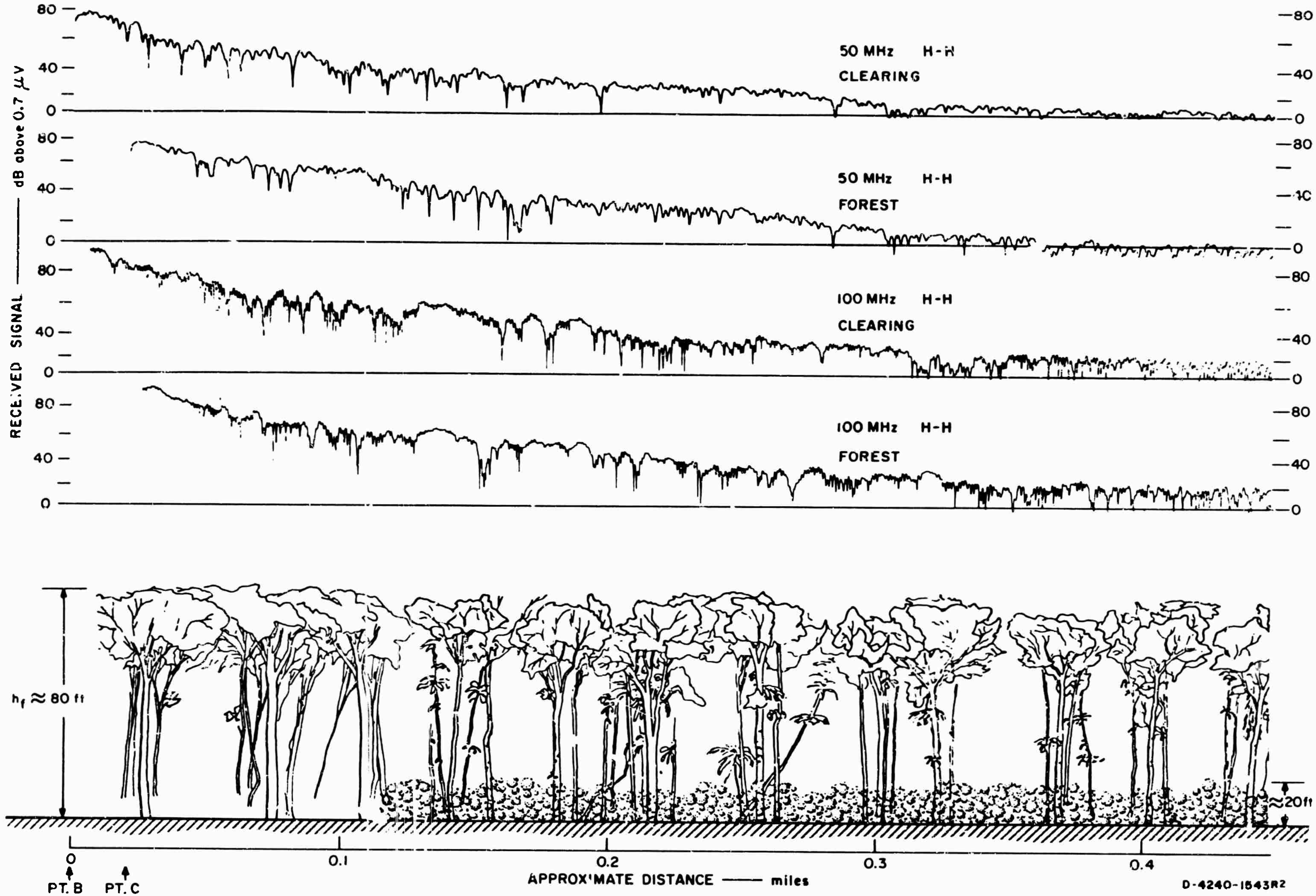

FIG. 18 SIGNALS RECEIVED IN A CLEARING (Point B) COMPARED WITH SIGNALS RECEIVED IN A FOREST (Point C) AS XELEDOP WAS CARRIED ALONG TRAIL A

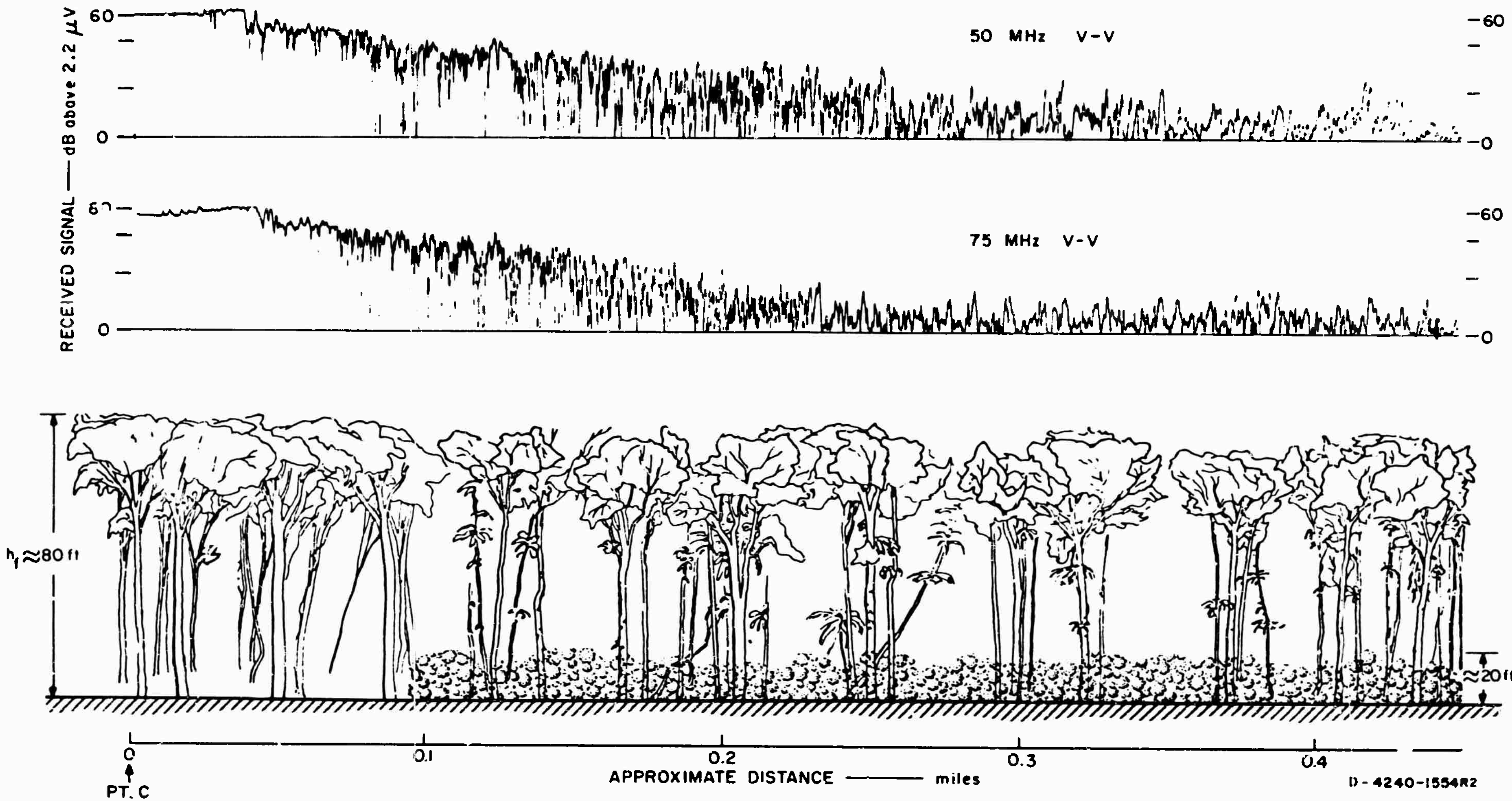

FIG. 19 AN/PRC-25 ALONG TRAIL A; RECEIVER IN FOREST (Point C) USING 10-FOOT WHIP ANTENNAS (AT-271/PRC)

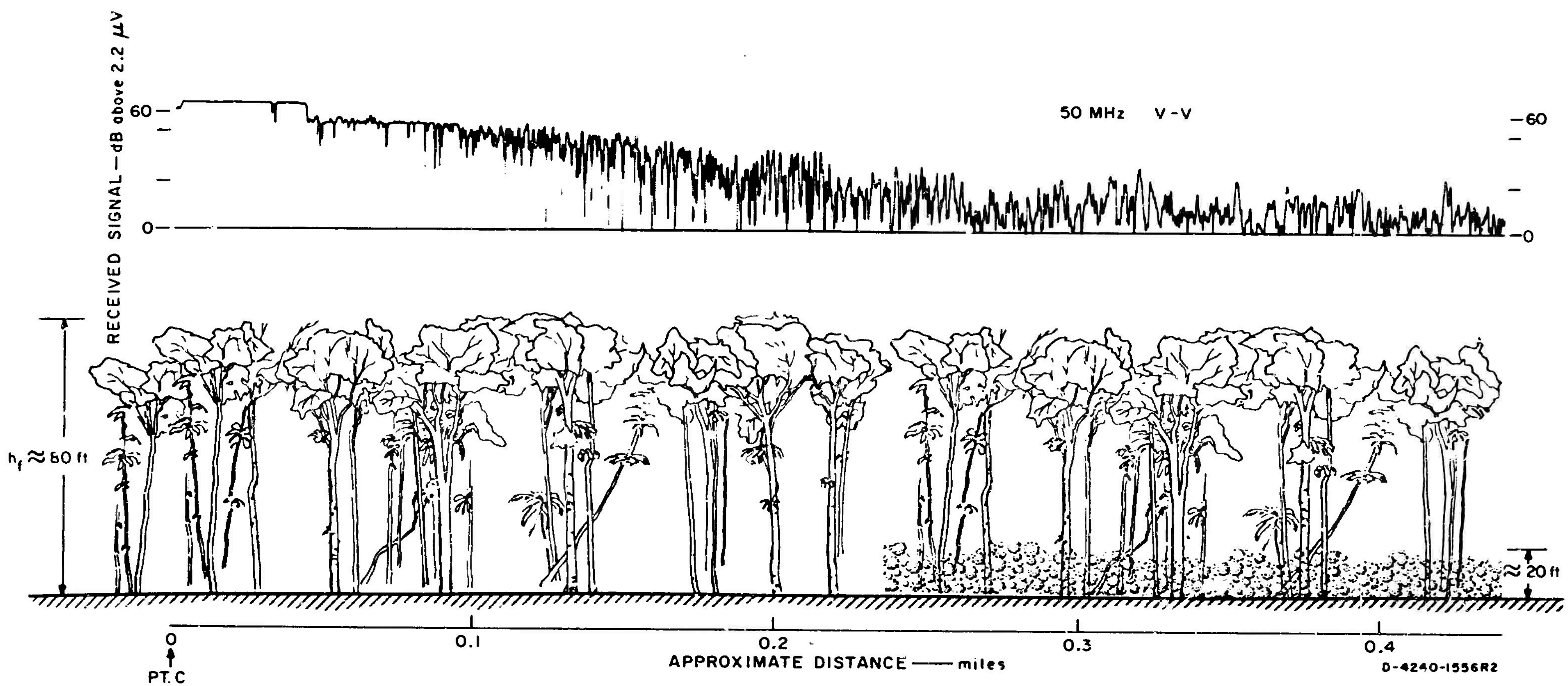

FIG. 20 AN/PRC-25 ALONG TRAIL A; RECEIVER IN FOREST (Point C) USING 10-FOOT WHIP ANTENNAS (AT-271/PRC) — UNDERGROWTH BETWEEN 0.1 AND 0.25 MILES REMOVED

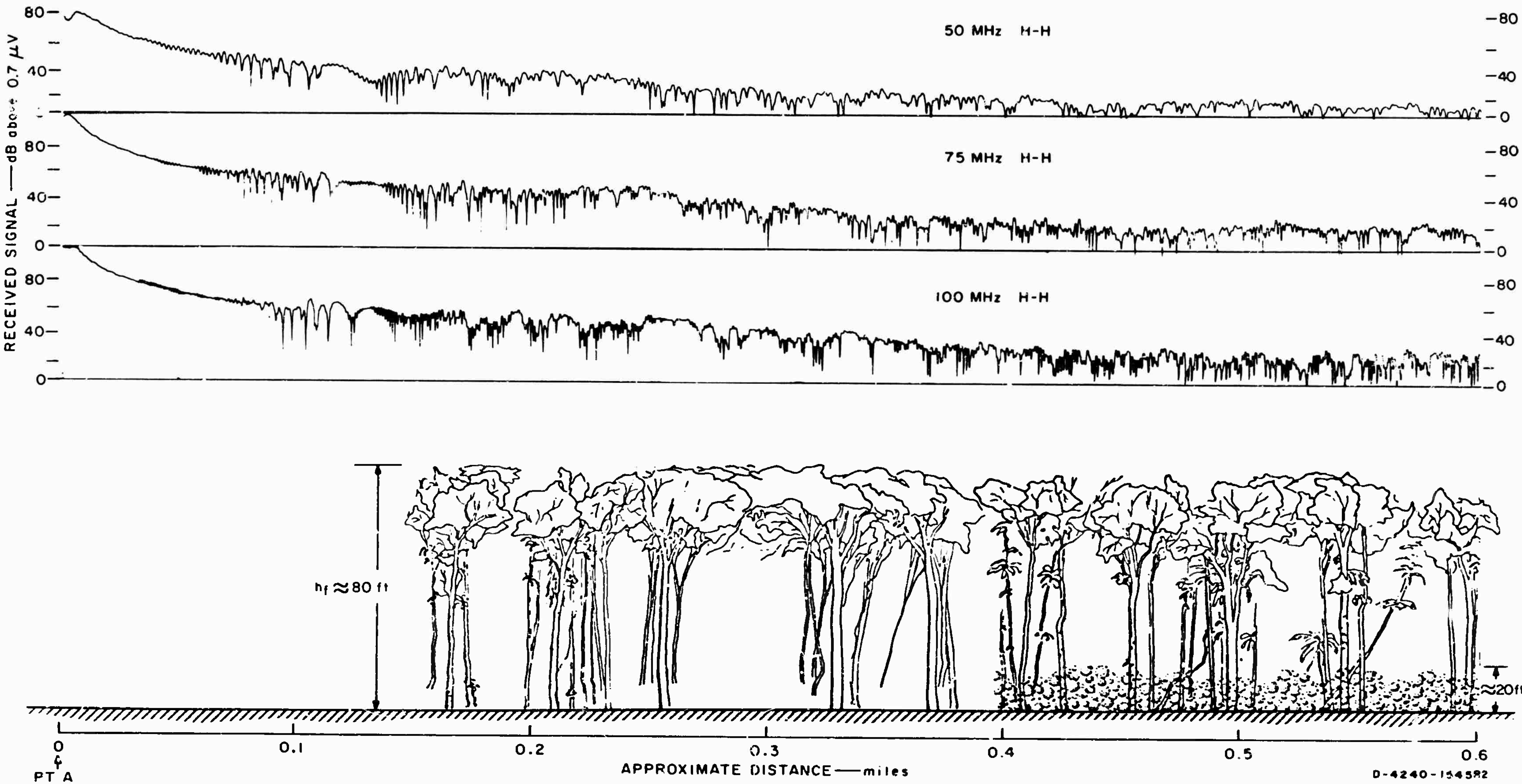

FIG. 21 BOUNDARY EFFECT: XELEDOP ALONG TRAIL A; UNBALANCED RECEIVING ANTENNAS IN CLEARING (Point A); HORIZONTAL POLARIZATION

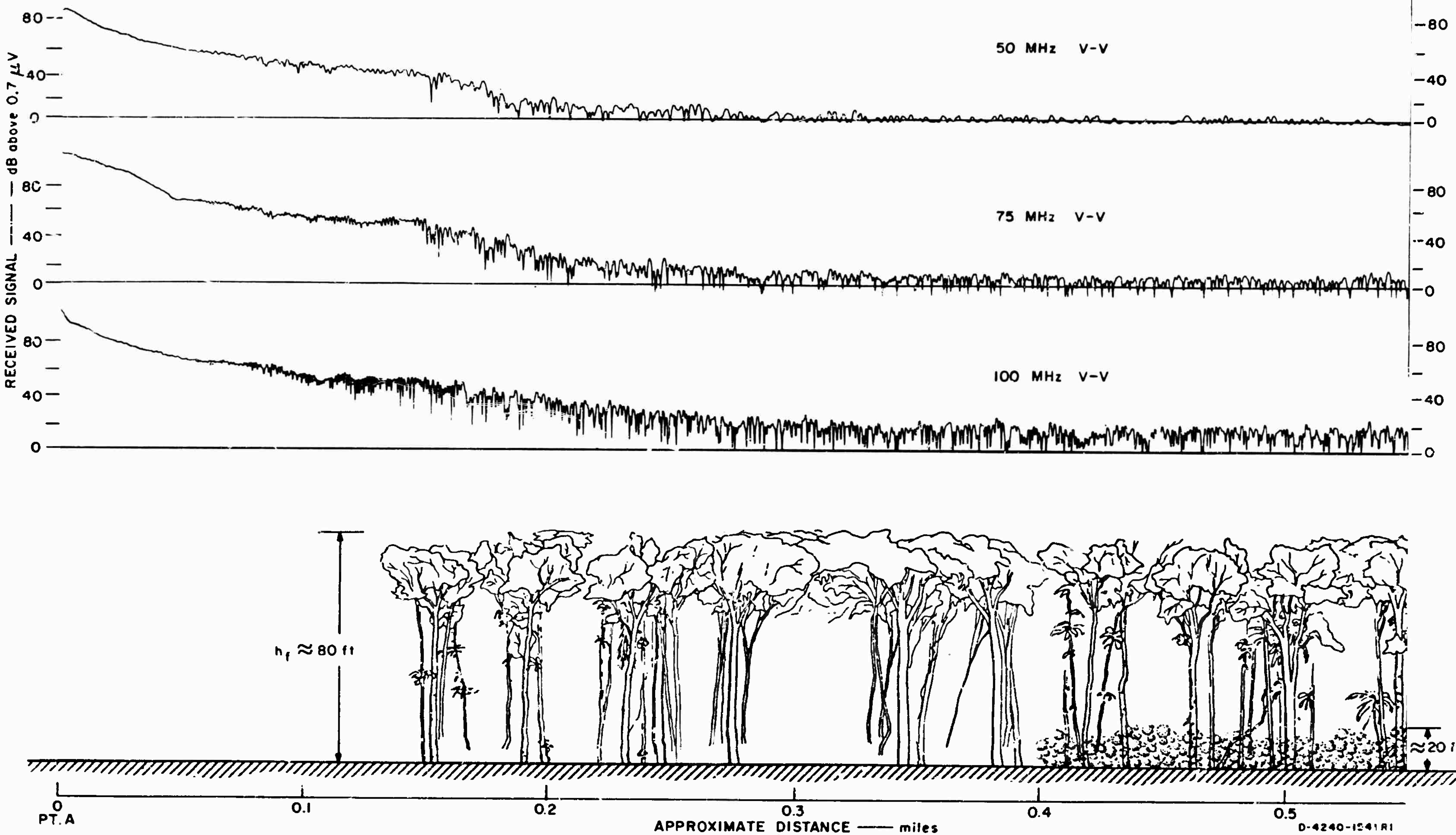

FIG. 22 BOUNDARY EFFECT: XELEDOP ALONG TRAIL A; UNBALANCED RECEIVING ANTENNAS IN CLEARING (Point A); VERTICAL POLARIZATION

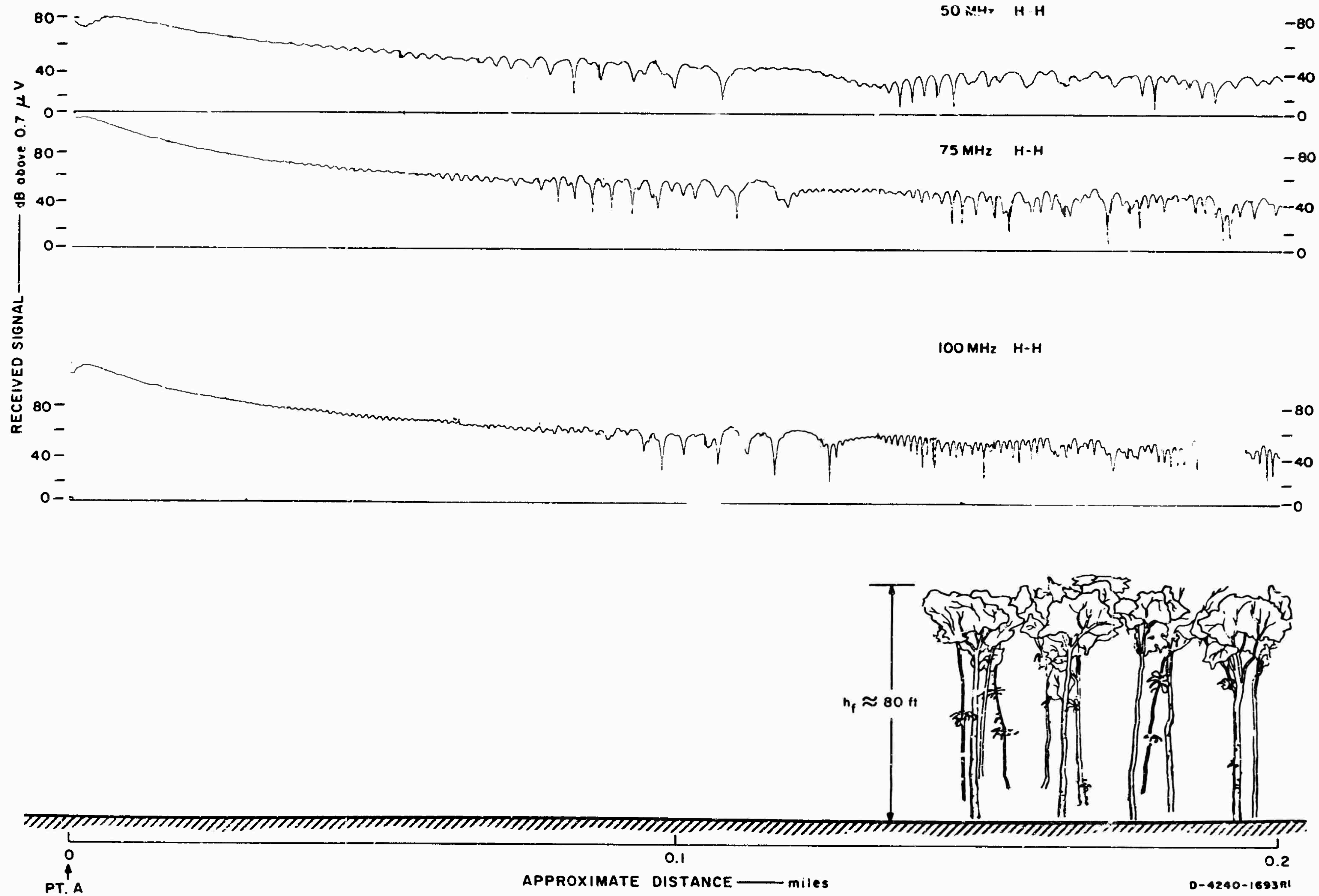

FIG. 23 BOUNDARY EFFECT: EXPANDED-SCALE VERSION OF FIG. 21

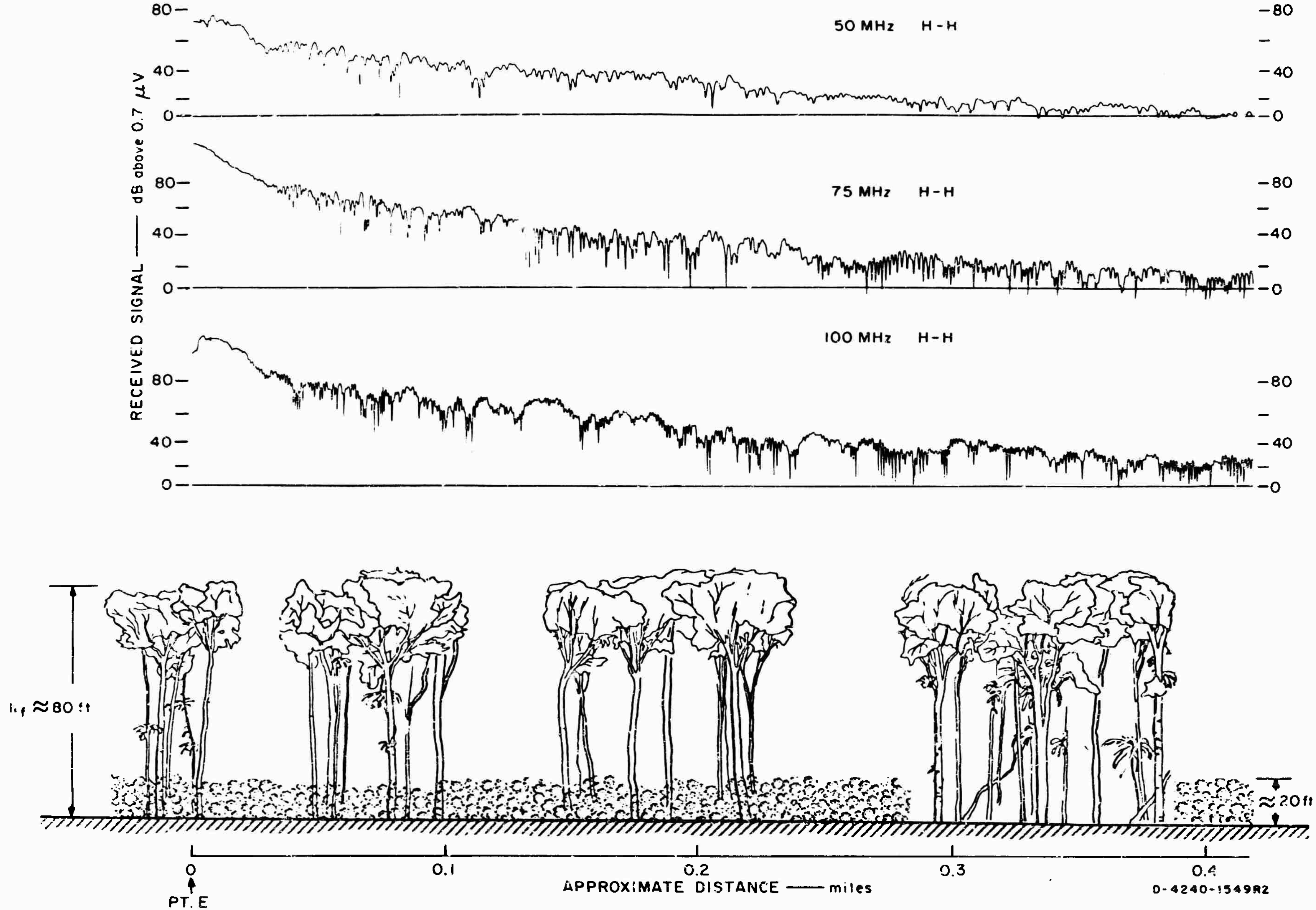

FIG. 24 XELEDOP ALONG TRAIL B; RECEIVING ANTENNAS IN FOREST (Point E); HORIZONTAL POLARIZATION

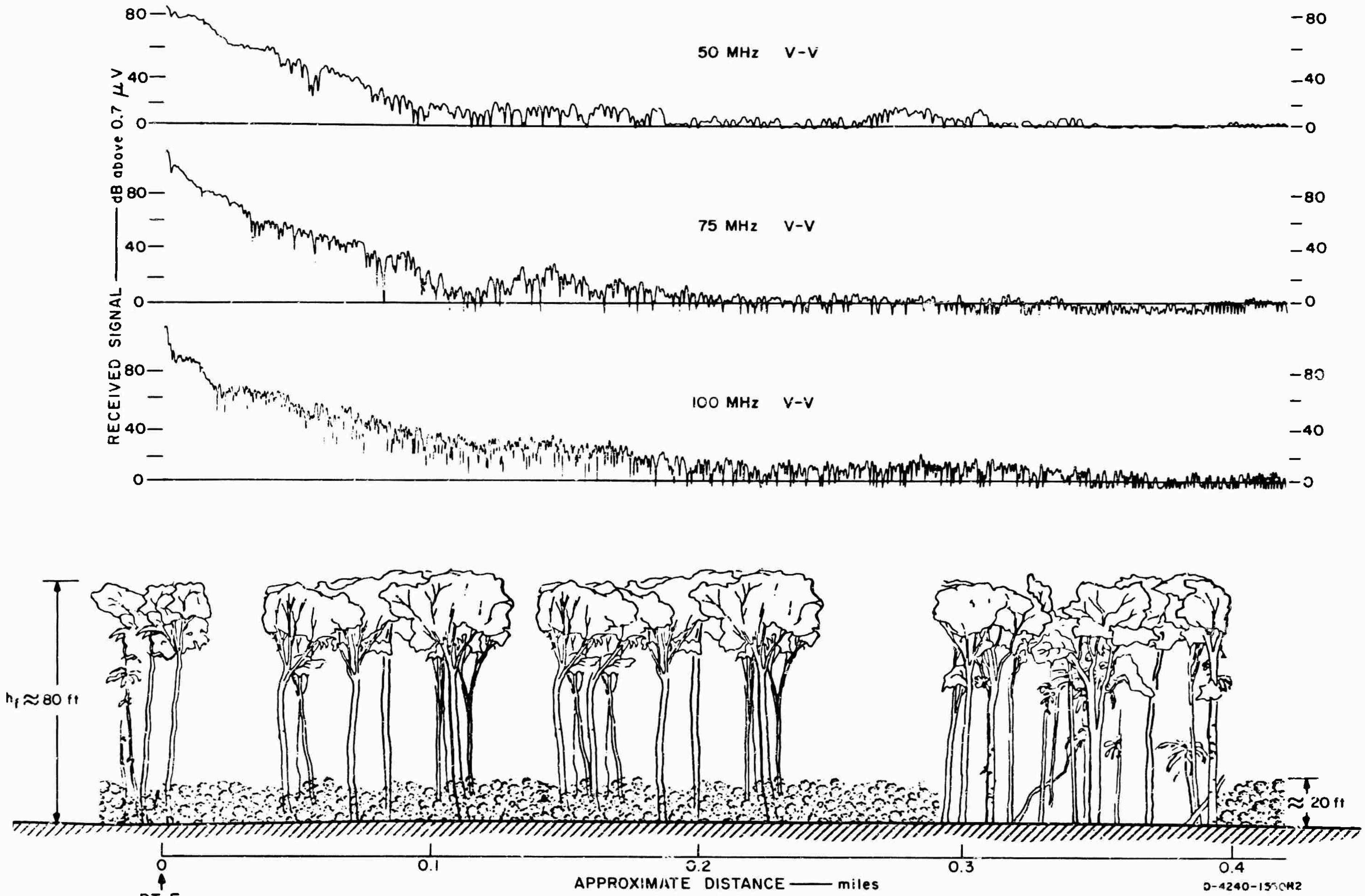

FIG. 25 XELEDOP ALONG TRAIL B; RECEIVING ANTENNAS IN FOREST (Point E); VERTICAL POLARIZATION

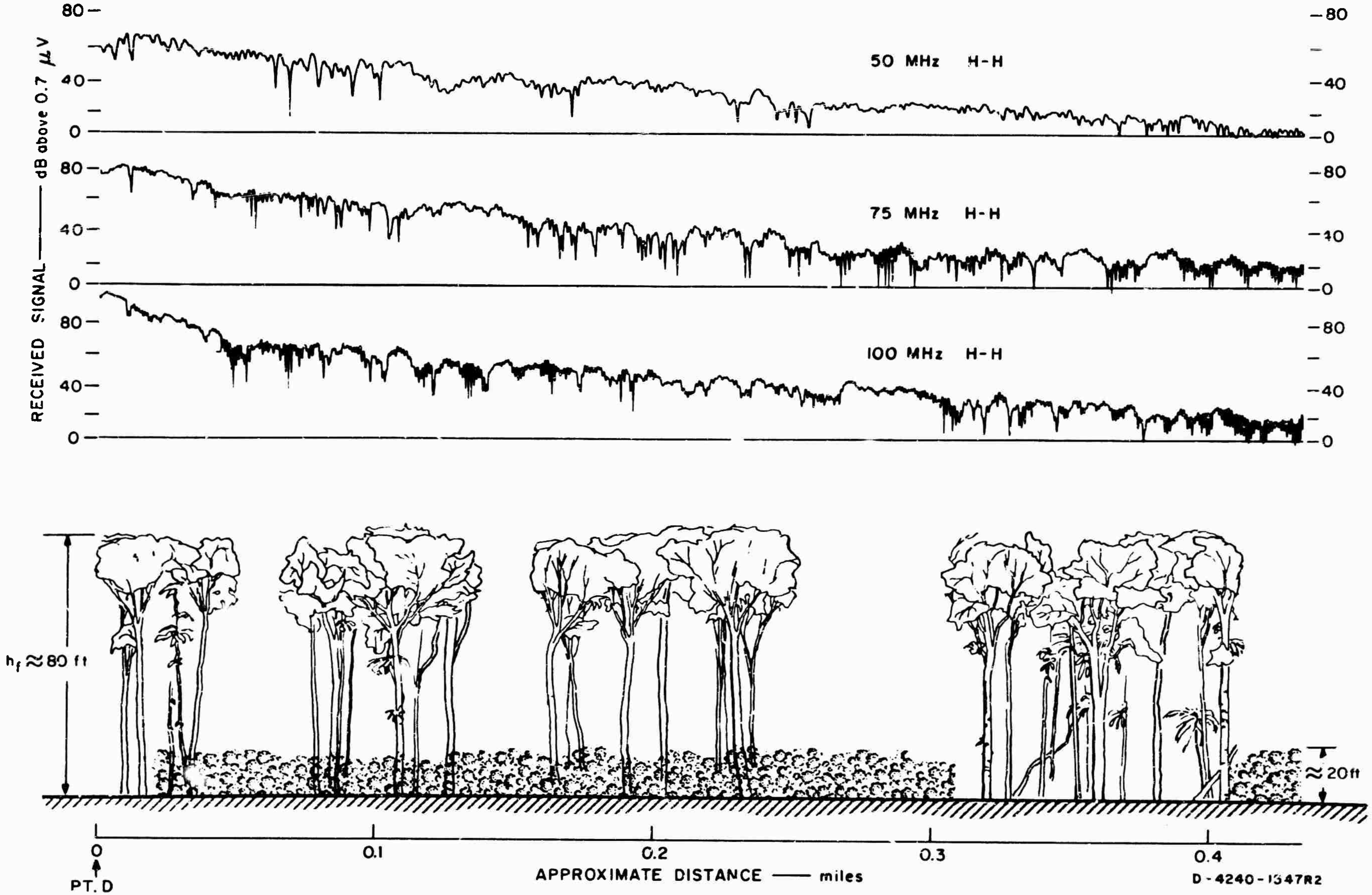

FIG. 26 XELEDOP ALONG TRAIL B; RECEIVING ANTENNAS IN CLEARING (Point D); HORIZONTAL POLARIZATION

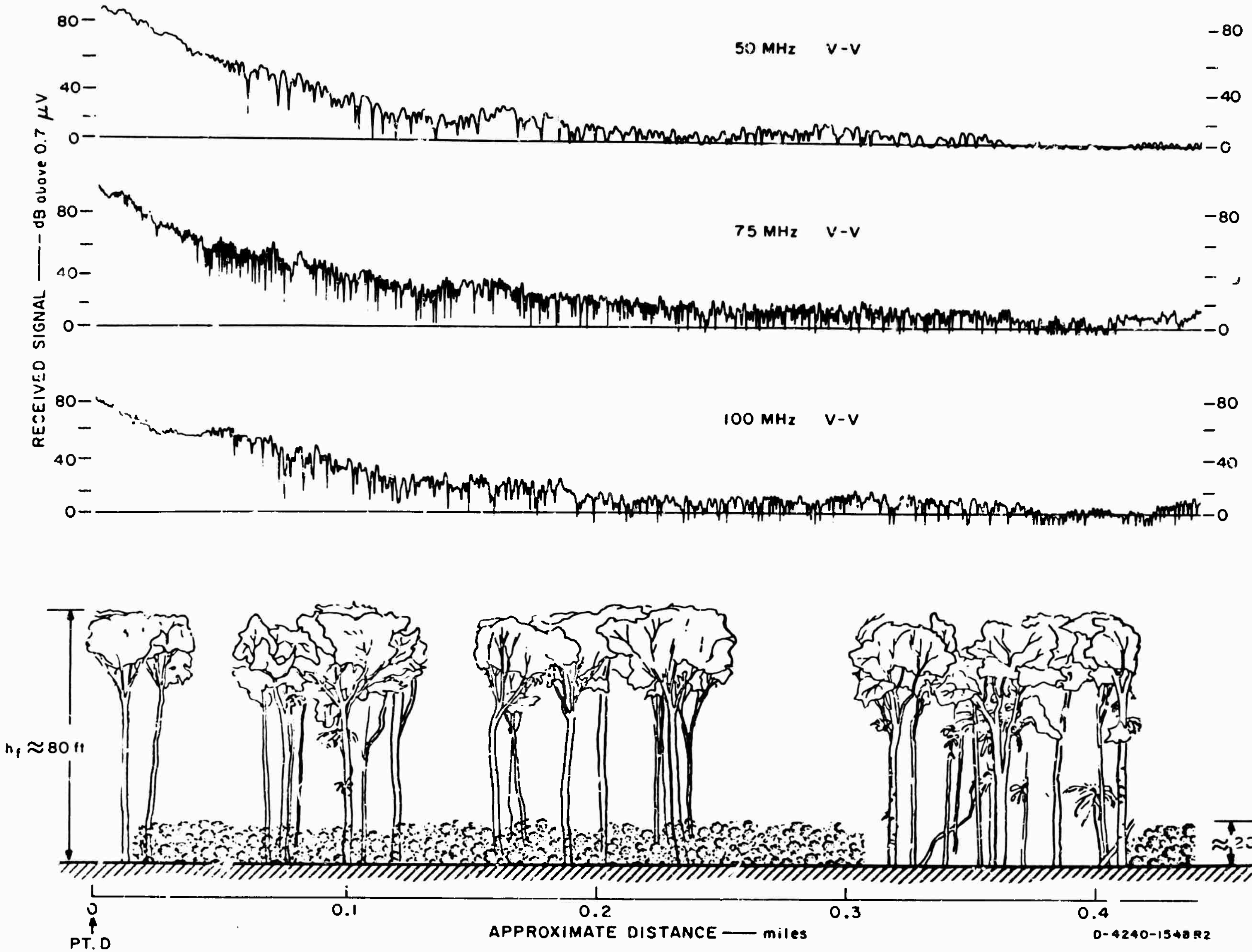

FIG. 27 XELEDOP ALONG TRAIL B; RECEIVING ANTENNAS IN CLEARING (Point D); VERTICAL POLARIZATION

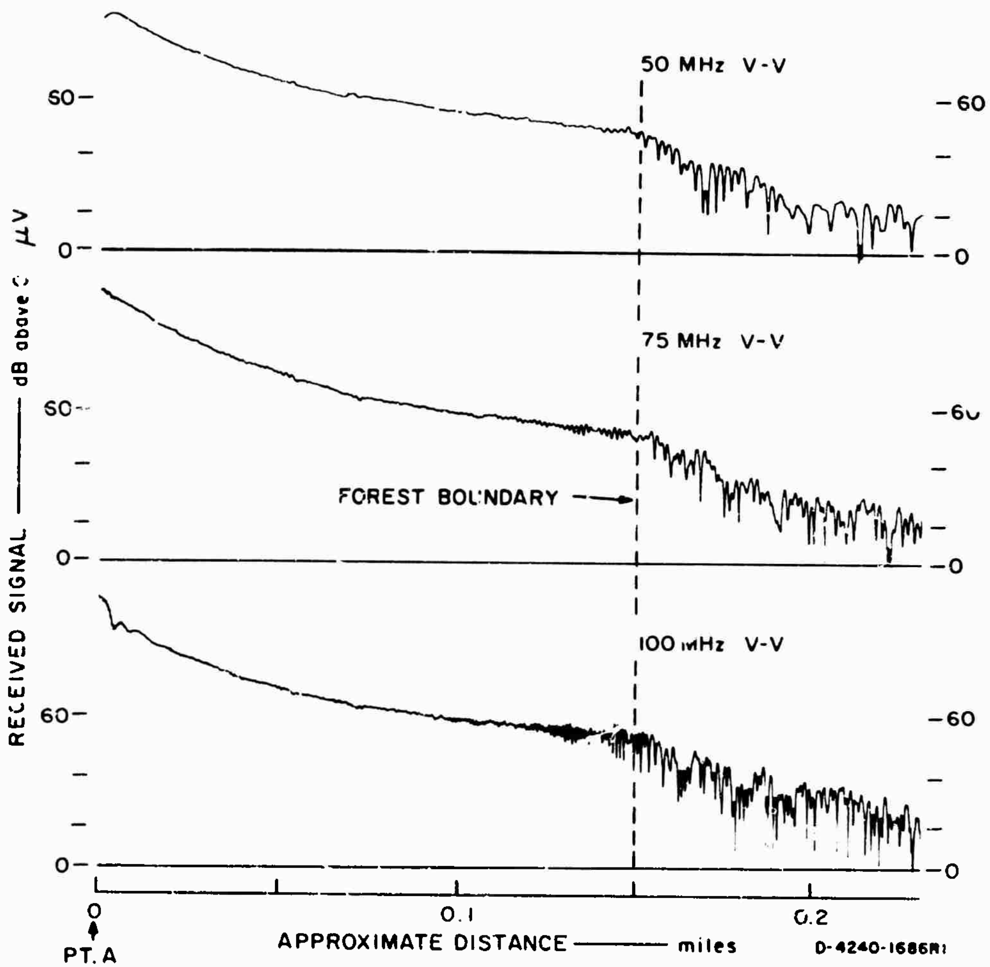

FIG. 28 BOUNDARY EFFECT: XELEDOP ALONG TRAIL R-1 (Rubber) UNBALANCED RECEIVING ANTENNAS IN CLEARING (Point A, Fig. 9); VERTICAL POLARIZATION

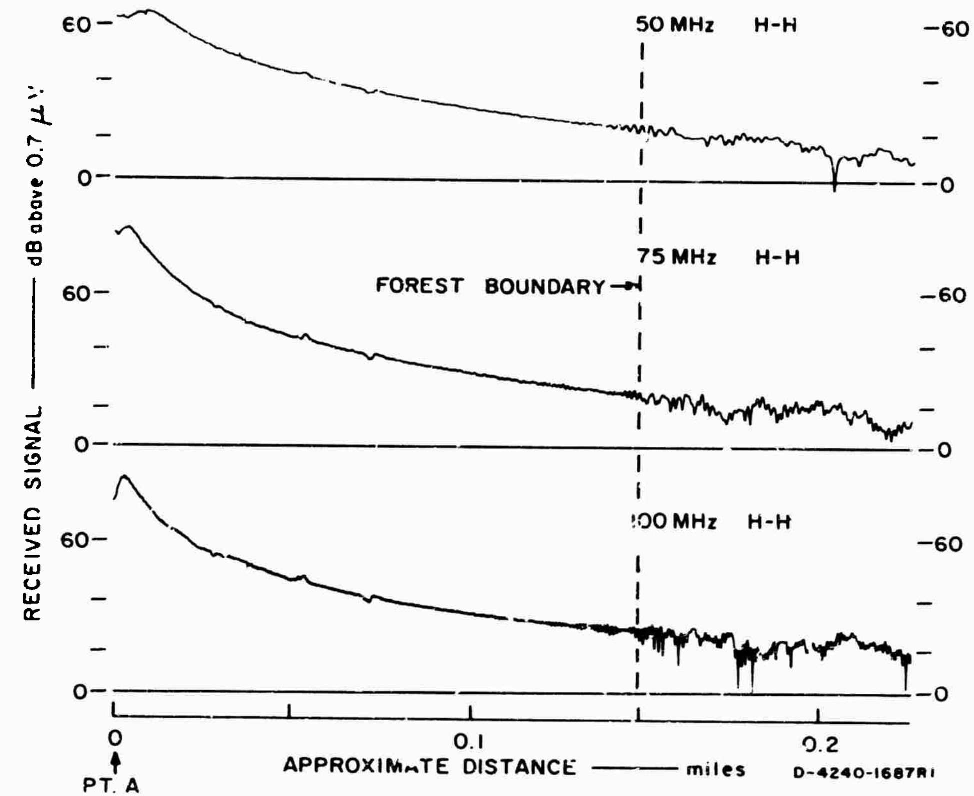

FIG. 29 BOUNDARY EFFECT: XELEDOP ALONG TRAIL R-1 (Rubber); UNBALANCED RECEIVING ANTENNAS IN CLEARING (Point A, Fig. 9); HORIZONTAL POLARIZATION

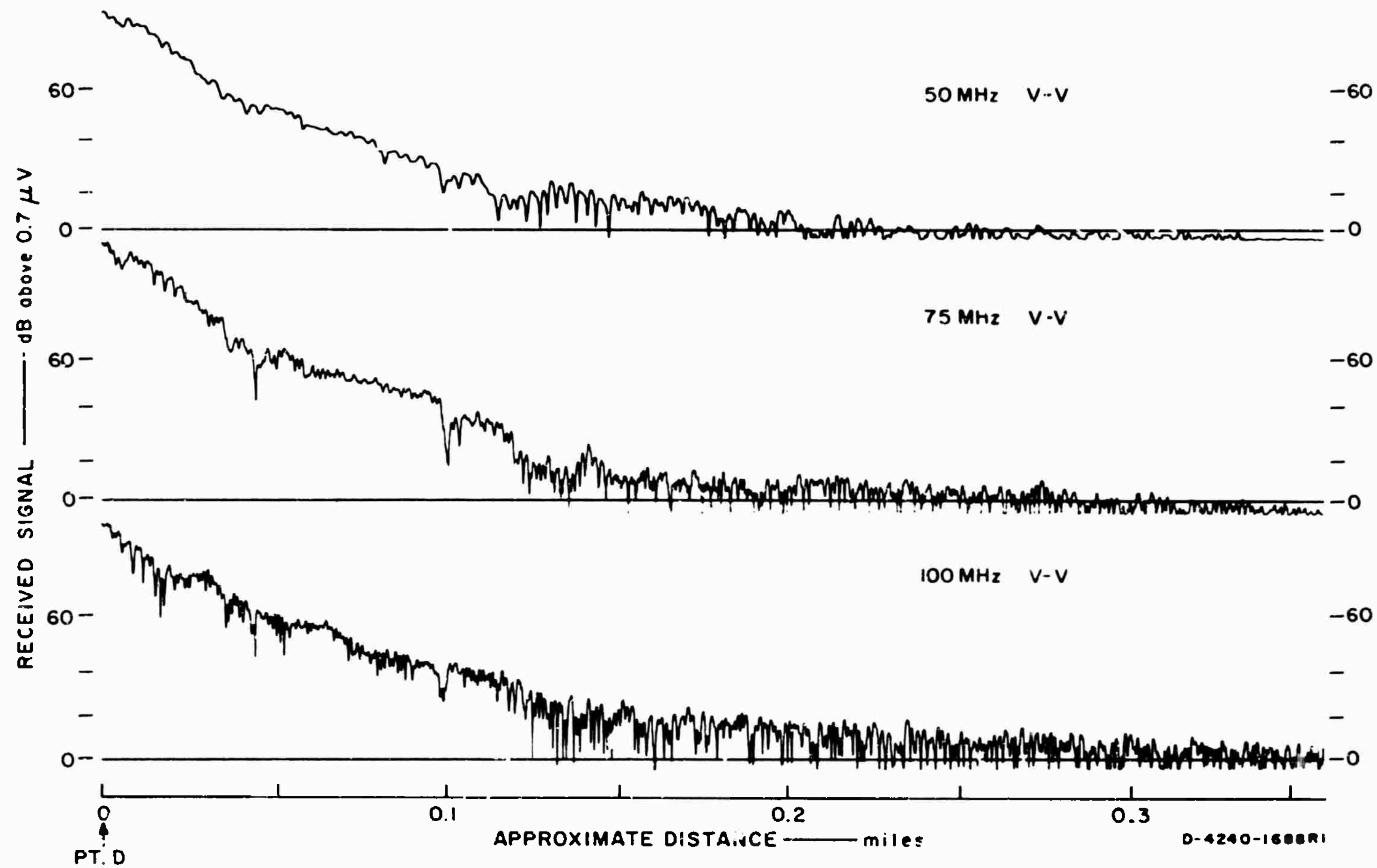

FIG. 30 VERTICAL POLARIZATION: XELEDOP ALONG TRAIL R-2 (Rubber); RECEIVING ANTENNAS IN FOREST (Point D, Fig. 9)

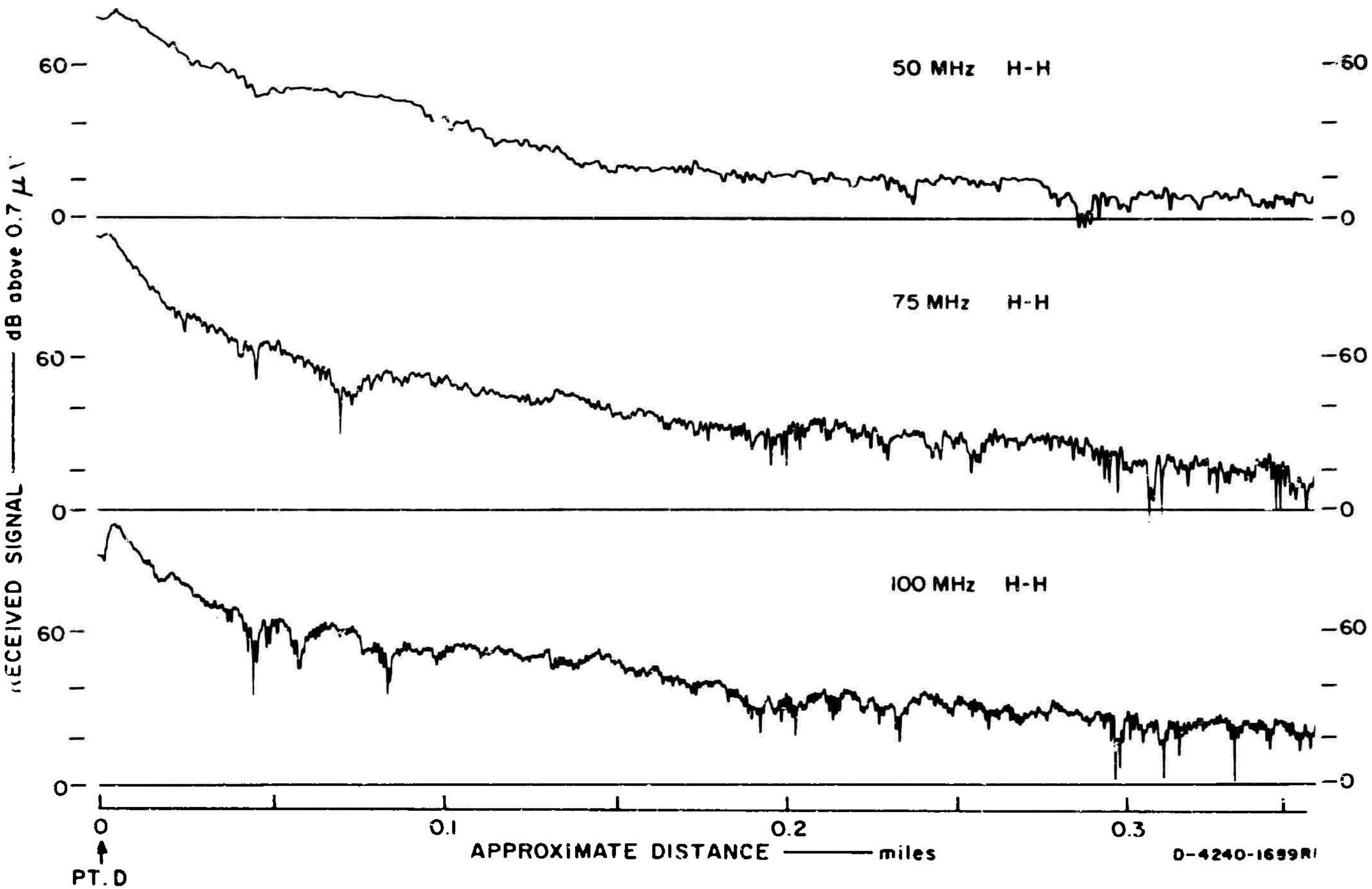

FIG. 31 HORIZONTAL POLARIZATION: XELEDOP ALONG TRAIL R-2 (Rubber); RECEIVING ANTENNAS IN FOREST (Point D, Fig. 9)

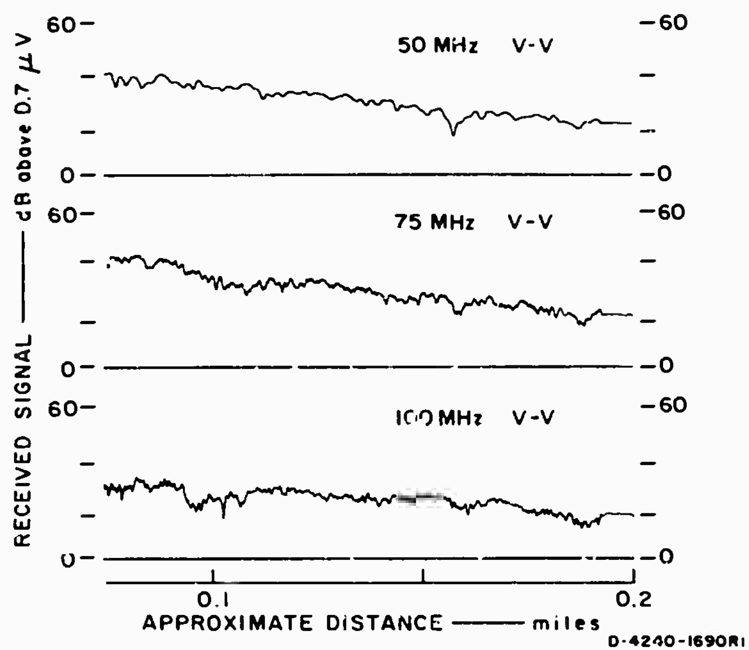

FIG. 32 VERTICAL POLARIZATION: XELEDOP ALONG BAMBOO; RECEIVING ANTENNAS IN BAMBOO (See Fig. 13)

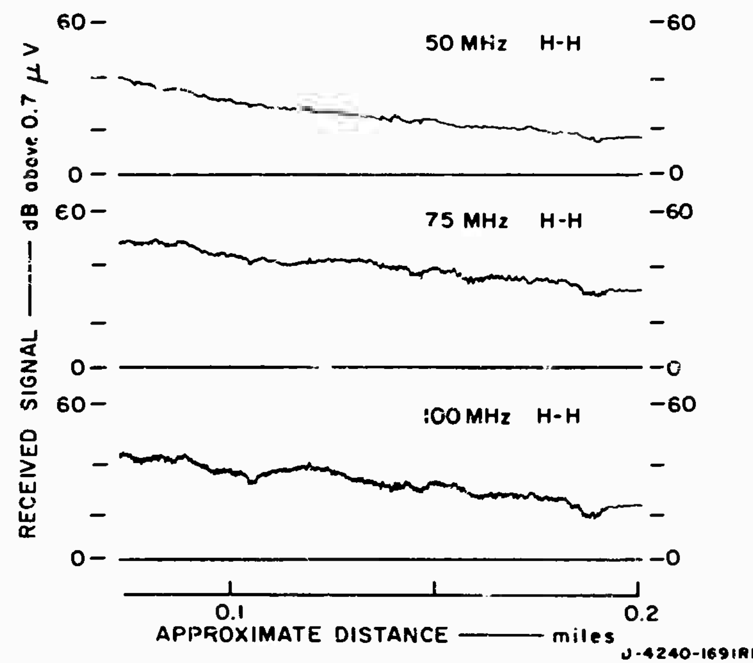

FIG. 33 HORIZONTAL POLARIZATION: XELEDOP ALONG BAMBOO; RECEIVING ANTENNAS IN BAMBOO (See Fig. 13)

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13. ABSTRACT

Slow-speed chart records of received signal strength showing the perturbations caused by scattering from trees in the VHF band are presented. Data for several frequencies and polarization of transmitting and receiving antennas (simple dipoles and standard AN/PRC-25 manpack-set whips) are included, as well as a variety of combinations of clearings, jungle terrain, rubber plantations, and bamboo. The records permit a qualitative evaluation of the magnitude of signal fading that is superimposed upon the smooth decrease of received signals with distance between transmitter and receiver. Some similar results are presented for an AN/PRC-25 manpack system using AT-271/PRC antennas.

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
VHF Propagation						
Southeast Asia						
Thailand						
Terrain Effects						
Foliage Effects						
Foliage Mensuration						
Manpack Radios						
Xeledop Technique						
Signal Strength						
SEACORE						